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STATE OF SEA PHOTOGRAPHS FOR
THE BEAUFORT WIND SCALE. 1968.

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STATE OF SEA PHOTOGRAPHS FOR THE BEAUFORT WIND SCALE

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CANADA

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THE BEAUFORT WIND SCALE

METEOROLOGICAL BRANCH

DEPARTMENT OF TRANSPORT

1968.

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FOREWORD

The chief purpose of this publication is to provide, by means of representative photographs illustrating the effects of wind on the sea surface, a pictorial guide to ships' officers and other shipboard weather observers for estimating the wind speed at sea.

The photographs were made by the Meteorological Staff of the Canadian Ocean Weather Ships C.C.G.S. ST. CATHARINES and C.C.G.S. STONETOWN. The assistance of Messrs. B. Middler, F. Bergwall, B.L. Smith and G. Wood of C.C.G.S. ST. CATHARINES, and Messrs. J.H. Scarlett, W.E. Murray and 2/0 B. Johnson of C.C.G.S. STONETOWN, is gratefully acknowledged.

The photographs presented in this report were selected under the direction of Mr. W.T.R. Allen, Marine Meteorologist, Meteorological Branch Headquarters.

for J.R.H. NOBLE, Director,
Meteorological Service of Canada.

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STATE OF SEA PHOTOGRAPHS FOR THE BEAUFORT WIND SCALE

INTRODUCTION

This report presents the results of a project carried out on board the Canadian Ocean Weather Ships ST. CATHARINES and STONETOWN. The aim of the project was to collect photographs of the sea surface as it appears under the influence of the various ranges of wind speed defined by The Beaufort Scale of Wind Force. Word descriptions of the appearance of the sea for each Beaufort Force have been available for many years, but it was felt that photographs illustrating the conditions associated with each force would be of some assistance to ships' officers in estimating wind speed. Sea photographs taken by low-flying aircraft of the United States Navy Air Force was published by the Meteorological Branch under a circular memorandum dated December 20, 1957. However, these aerial photographs, while good, do not depict the aspect of the sea as viewed from the bridge of a ship. The apparent lack of good photographs of this nature prompted this project on the Ocean Weather Ships. A selection of the best photographs resulting from the project are presented in this report.

ESTIMATING THE WIND AT SEA

Observers on board ships at sea usually determine the speed of the wind by estimating its Beaufort Force, as merchant ships are not normally equipped with wind measuring instruments. Through experience, ships' officers have developed various methods of estimating this Force. The effect of the wind on the observer himself, the ship's rigging, flags, etc., is used as a criterion; but estimates based on these indications give the relative wind which must be corrected for the motion of the ship before an estimate of the true wind speed can be obtained.

The most common method involves the appearance of the sea surface. The state of the sea disturbance, i.e. the dimensions of the waves, the presence of white horses, foam or spray, depends principally on three factors, as follows:–

1. *The wind speed.* The higher the speed of the wind, the greater the sea disturbance.
2. *The duration of the wind.* At any point on the sea, the disturbance will increase the longer the wind blows at a given speed, until a maximum state of disturbance is reached.
3. *The fetch.* This is the length of the stretch of water over which the wind acts on the sea surface from the same direction. For a given wind speed and duration, the longer the fetch, the greater the sea disturbance. If the fetch is short, say a few miles, the disturbance will be relatively small no matter how great the wind speed is or how long it has been blowing.

There are other factors which can modify the appearance of the sea surface caused by wind alone. These are strong currents, shallow water, swell, precipitation, ice, and wind shifts. Their affects will be described later.

A wind of a given Beaufort Force will, therefore, produce a characteristic appearance of the sea surface provided that it has been blowing for a sufficient length of time, and over a sufficiently long fetch. The effects of currents, shallow water, swell, precipitation, etc., should also be absent. The "Sea Criteria" associated with each Beaufort Force from Force 0 to Force 12 were agreed upon and drawn up by the International Meteorological Committee in 1939. These word descriptions of the state of the sea, known as the Sea Criterion of the Beaufort Scale of Wind Force, are shown in Table I.

The use of the Sea Criterion has the advantage that the speed of the ship need not be considered. In practice the mariner observes the sea surface, noting the size of the waves, the white horses, spindrift, etc., and then finds the criterion, as in Table I, which best describes the sea surface as he saw it. This criterion is associated with a Beaufort number, for which a corresponding mean wind speed and range in knots are given. Since meteorological reports require that wind speeds be reported in knots, the mean speed

for the Beaufort number may be reported, or an experienced observer may judge that the sea disturbance is such that a higher or lower speed within the range for the force is more accurate.

This method, while it appears simple, should be used with caution however. It should be borne in mind that the sea conditions described for each Beaufort Force in Table I are "steady-state" conditions; i.e. the conditions which result when the wind has been blowing for a relatively long time, and over a great stretch of water. At any particular time at sea, though, the duration of the wind or the fetch, or both, may not have been great enough to produce these "steady-state" conditions. When a high wind springs up suddenly after previously calm or near calm conditions, it will require some hours, depending on the strength of the wind, to generate waves of maximum height. The height of the waves increases rapidly in the first few hours after the commencement of the blow, but increases at a much slower rate later on. Considering the effect of fetch, if the observer could start at the beginning of the fetch, (say at a coast-line when the wind is offshore), after the wind has been blowing for a long time, and proceed downwind, he would notice that the waves were quite small at the beginning, and increased in height rapidly over the first 50 miles or so of the fetch. Farther along he would notice that the rate of increase in height with distance would slow down, and after 500 miles or so from the beginning of the fetch there would be little or no increase in height.

To illustrate the duration of winds and the length of fetches required for various wind forces to build seas to 50%, 75%, and 90% of their theoretical maximum heights, Table II* is of interest.

The theoretical maximum wave heights represent the average heights of the highest third of the waves, as these waves are of the most practical significance.

It will be seen that winds of Force 5 or less can build seas to 90% of their maximum height in less than 12 hours, provided the fetch is long enough. Higher winds require a much greater time – Force 11 winds requiring 32 hours to build waves to 90% of their maximum height. The times given in Table II represent those required to build waves starting from initially calm sea conditions. If waves are already present at the onset of the blow, the times would be somewhat less depending on the initial wave heights and their direction relative to the direction of the wind which has sprung up.

The first consideration when using the sea criterion to estimate wind speed, therefore, is to decide whether the wind has been blowing long enough from the same direction to produce a steady state sea condition. If not, then it is possible that the wind speed may be underestimated. For example, if a wind with an actual speed of

*Derived from Sverdrup, H.U., and Munk, W.H., "Wind, Sea, and Swell, Theory of Relations for Forecasting", H.O. Pub. No. 601, 1947-

TABLE II

Beaufort Force of Wind	Theoretical Maximum wave height (ft) unlimited duration and fetch.	Duration of winds, (hours), with unlimited fetch, to produce percent of maximum wave height indicated.			Fetch (nautical miles), with unlimited duration of blow, to produce percent of maximum wave height indicated.		
		50%	75%	90%	50%	75%	90%
3	2	1.5	5	8	3	13	25
5	8	3.5	8	12	10	30	60
7	20	5.5	12	21	22	75	150
9	40	7	16	25	55	150	280
11	70	9	19	32	85	200	450

TABLE I – BEAUFORT SCALE OF WIND FORCE

Beaufort Number	Mean Wind Speed in knots	Limits of Wind Speed in knots	Descriptive Terms	Appearance of the Sea if the fetch and duration of the blow have been sufficient to develop of the sea fully	Probable Wave Height* in Feet	Probable Maximum Wave Height* in Feet
0	0	1	Calm	Sea like a mirror	0	0
1	2	1–3	Light air	Ripples with the appearance of scales are formed, but without foam crests.	¼	¼
2	5	4–6	Light Breeze	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break.	½	½
3	9	7–10	Gentle Breeze	Large wavelets; crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.	2	3
4	13	11–16	Moderate Breeze	Small waves, becoming longer. Fairly frequent white horses.	3½	5
5	19	17–21	Fresh Breeze	Moderate waves, taking a more pronounced long form. Many white horses are formed. Chance of some spray.	6	8½
6	24	22–27	Strong Breeze	Large waves begin to form. The white foam crests are more extensive everywhere. (Probably some spray).	9½	13
7	30	28–33	Near Gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	13½	19
8	37	34–40	Gale	Moderately high waves of greater length. Edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind.	18	25
9	44	41–47	Strong Gale	High waves; dense streaks of foam along the direction of the wind. Crests begin to topple, tumble, and roll over. Spray may affect visibility.	23	32
10	52	48–55	Storm	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected.	29	41
11	60	56–63	Violent Storm	Exceptionally high waves. (Small and medium sized ships might be for a time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	37	52
12	68	64–71	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray. Visibility very seriously affected.	45	–

*The last two columns are added as a guide to show roughly what may be expected in the open sea, remote from land. In enclosed waters, or when near land with an off-shore wind, wave heights will be smaller and the waves steeper. The probable maximum wave height is reached by about one wave in ten.

Force 9 has been blowing for only 7 hours, it may have generated a sea condition which would perhaps correspond to a steady state for Force 6, If, in this case, the sea criterion was used blindly without considering the short duration, and Force 6 was reported, then the wind would be underestimated by three Beaufort Forces, or approximately 20 knots. This is an extreme example however, as it is very unlikely that even an inexperienced seaman could not distinguish a Force 6 from a Force 9 wind.

Experience has shown that the appearance of white horses, foam, spindrift, etc., reaches a steady state condition before the height of the waves attain their maximum value. It is a safe assumption that the appearance of the sea (as regards white horses, etc.) will reach a steady state in the time required to build the waves to 50% to 75% of their maximum height. Thus, from Table II, it is seen that a Force 5 wind could require 8 hours at most to produce a characteristic appearance of the sea surface.

A second consideration when using the sea criterion is the length of the fetch over which the wind has been blowing to produce the present state of the sea. On the open sea, unless the mariner has a copy of the latest synoptic weather map available, he will not know the length of the fetch. It will be seen from Table II, though, that only relatively short fetches are required for the lower wind forces to generate their characteristic seas. On the open sea, the fetches associated with most storms and other weather systems are usually long enough so that even winds up to Force 9 can build seas up to 90% or more of their maximum height, providing the wind blows from the same direction long enough.

When navigating close to a coast or in restricted waters, however, it may be necessary to make allowances for the shorter stretches of water over which the wind blows. For example, referring to Table II, if the ship is 22 miles from a coast and an offshore wind with an actual speed of Force 7 is blowing, the waves at the ship will never attain more than 50% of their maximum height for this speed no matter how long the wind blows. Hence, if the sea criterion were used under these conditions without consideration of the short fetch, the wind speed would be underestimated. With an offshore wind, the sea criterion may be used with confidence if the distance to the coast is greater than the values given in the extreme right-hand column of Table II; again, provided that the wind has been blowing offshore for a sufficient length of time.

Other factors aside from the duration of the blow and the fetch affect the appearance of the sea surface, and should be considered if they are present.

Tides and Currents

A wind blowing against a tide or strong current causes a greater sea disturbance than normal, which may result in an overestimate of the wind speed. On the other hand, a wind blowing in the same direction as a tide or strong current causes less sea disturbance than normal, and may result in an underestimate of the wind speed.

Shallow Water

Waves running into shallow water increase in steepness, and hence, their tendency to break. With an onshore wind there will, therefore, be more white horses over the shallow waters than over the deeper water farther offshore. It is only over relatively deep water that the sea criterion can be used with confidence.

Swell

Swell is the name given to waves, generally of considerable length, which were raised in some distant area by winds blowing there, and which have moved into the vicinity of the ship; or to waves raised nearby and which continue to advance after the wind at the ship has abated or changed direction. The direction of swell waves is usually different from the direction of the wind and the sea waves. *Swell waves are not to be considered when estimating wind speed and direction. Only those waves raised by the wind blowing at the time are of any significance.* The wind-driven waves show a greater tendency to break when superimposed on the crests of swell, and hence more white horses may be formed than if the swell were absent. Under these conditions the use of the sea criterion may result in a slight overestimate of the wind speed.

Precipitation

Heavy rain has a damping or smoothing effect on the sea sur-

face which must be mechanical in character. Since the sea surface will therefore appear less disturbed than would be the case without the rain, the wind speed may be underestimated unless the smoothing effect is taken into account.

Ice

Even small concentrations of ice floating on the sea surface will dampen waves considerably, and concentrations greater than about seven tenths average will eliminate waves altogether. Young sea ice, which in the early stages of formation has a thick soupy consistency, and later takes on a rubbery appearance, is very effective in dampening waves. Consequently, the sea criterion cannot be used with any degree of confidence when sea ice is present. In higher latitudes, the presence of an ice field some distance to windward of the ship may be suspected if, when the ship is not close to any coast, the wind is relatively strong but the seas abnormally underveloped. The edge of the ice field acts like a coastline, and the short fetch between the ice and the ship is not sufficient for the wind to develop the seas fully.

Windshifts

Following a rapid change in the direction of the wind, as occurs at the passage of a cold front, the new wind will flatten out to a great extent the waves which were present before the windshift. This is so because the direction of the wind after the shift may differ by 90° or more from the direction of the waves, which does not change. Hence, the wind may oppose the progress of the waves and dampen them out quickly. At the same time the new wind begins to generate its own waves on top of this dissipating swell, and it is not long before the cross pattern of waves gives the sea a "choppy" or confused appearance. It is during the first few hours following the windshift that the appearance of the sea surface may not provide a reliable indication of the wind speed. The wind is normally stronger than the sea would indicate, as old waves are being flattened out, and new waves are just beginning to be developed.

Night Observations

On a dark night, when it is impossible to see the sea clearly, the observer may estimate the apparent wind from its effect on the ship's rigging, flags, etc., or simply the "feel" of the wind. A guide to estimating the apparent wind is given in the Meteorological Branch publication "Manual of Marine Weather Observing" (MANMAR), to which the observer is referred. Tables for converting the apparent wind to true wind may also be found in MANMAR.

THE STATE OF SEA PHOTOGRAPHS

The photographs were taken by the Meteorological Branch personnel of the Canadian Ocean Weather Ships ST. CATHARINES and STONETOWN which occupy Ocean Weather Station "P" in the North Pacific Ocean at 50°N, 145°W, or approximately 1,000 miles west of Vancouver. The ships man the station for alternate periods of six weeks.

The photographs were taken between March, 1960 and May, 1961. In this period a total of 247 photographs were obtained. Zeiss Ikon (2¼ × 3¼) cameras and Kodak Verichrome Pan film were used.

Of the 247 pictures available, two pictures were chosen to illustrate conditions associated with each Beaufort Force from Force 1 to Force 10. Only one picture was considered acceptable to illustrate Force 0. No representative photographs were available to illustrate Force 11 conditions, and no photographs were made of Force 12 conditions.

In selecting the pictures for presentation here, it was considered that they should meet two requirements. Firstly, a picture illustrating the effects of a given wind force should conform as closely as possible to the Sea Criterion for that force as given in Table I. Secondly, the wind prior to the time of the picture should be relatively steady both in direction and at the given force over many hours to ensure that near steady-state sea conditions for that force at the time of the picture existed. A large percentage of the photographs available were rejected because the wind at the time of the picture had not been blowing long enough to produce a disturbance of near steady-state proportion.

The pictures which follow were judged to fulfill best the requirements stated above. Opposite each picture is the accompanying technical and other data appropriate to each. In addition to the wind at the time of the photograph, the wind at three-hourly

intervals over the previous 24 hours is also included. The height of the ships' anemometers above the sea surface was approximately 60 feet. The synoptic weather situation at the time of the picture is described briefly, and other comments are given when warranted.

FORCE 0

Wind Speed less than 1 knot

Sea Criterion: Sea like a mirror.

Date/Time of photograph: June 5, 1960, 2340 G.M.T.

Height of camera above sea: 35 Feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2340 G.M.T.	–	Calm
2100	190	01
1800	080	03
1500	040	07
1200	040	09
0900	030	10
0600	030	11
0300	030	11
0000	040	10

WAVES AT TIME OF PICTURE

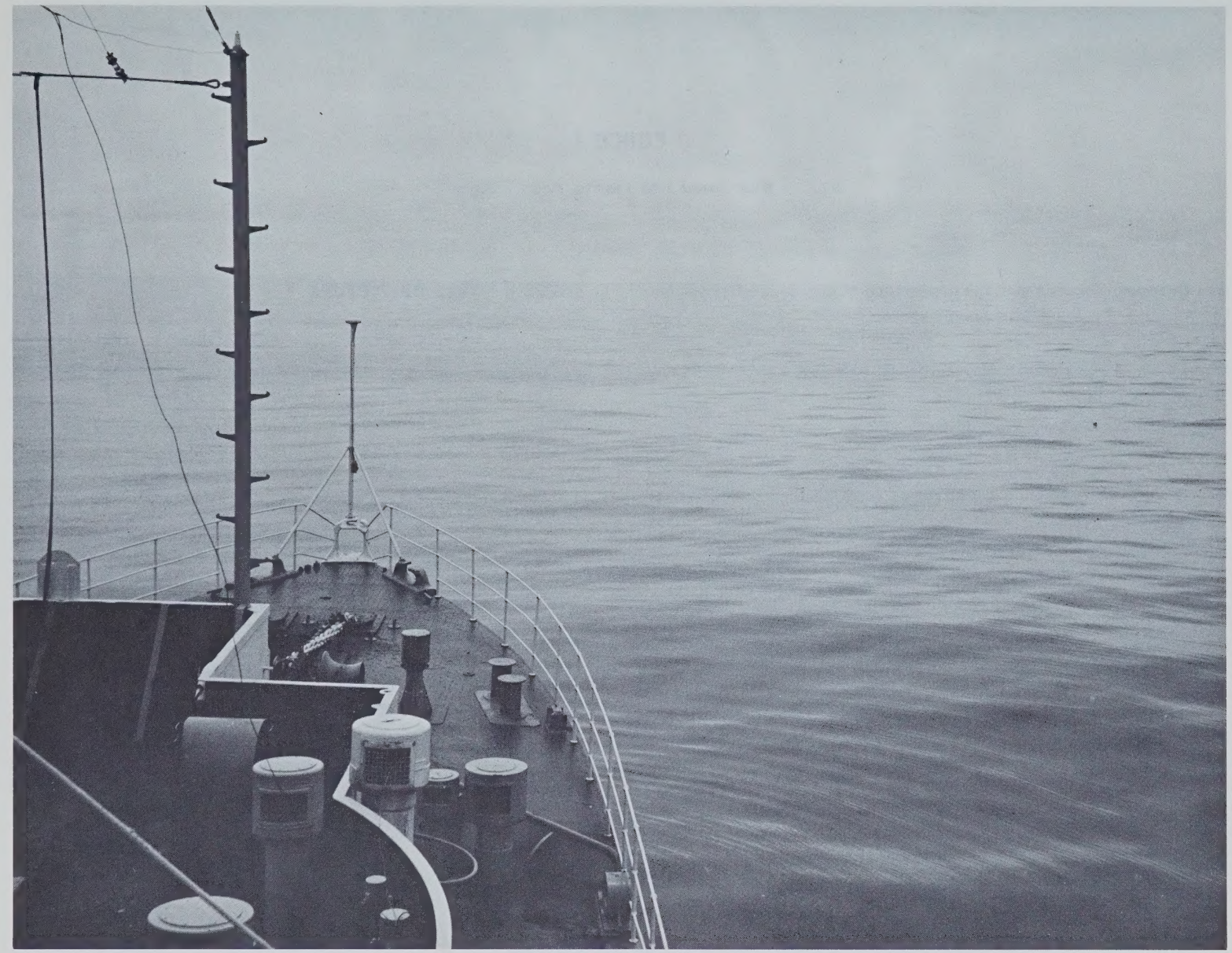
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	–	–	–
Swell	100°	5	2

SYNOPTIC SITUATION

High pressure area centred at 49°N, 144°W, or approximately 50 nautical miles southeast of ship at time of picture. Centre of high moving south-easterly.

REMARKS

Calm winds, and hence calm sea conditions, are rare at Station "P", occurring only about 1.5% of the time during the course of a year. Although the wind was essentially calm during the three hours prior to this photograph, it averaged 4 knots (Force 2) over the previous 12 hours, and 7 knots (Force 3) in the previous 24 hours. Air temperature 52.2°F, Sea Temperature 45.7°F.



BEAUFORT FORCE 0

FORCE 1

Wind Speed 1 to 3 knots, mean 2 knots

Sea Criterion: Ripples with the appearance of scales are formed, but without foam crests.

Date/Time of Photograph: May 22, 1960, 2000 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2000 G.M.T.	290	02
1800	–	Calm
1500	220	04
1200	260	08
0900	280	02
0600	–	Calm
0300	290	10
0000	290	12
2100	290	13

WAVES AT TIME OF PICTURE

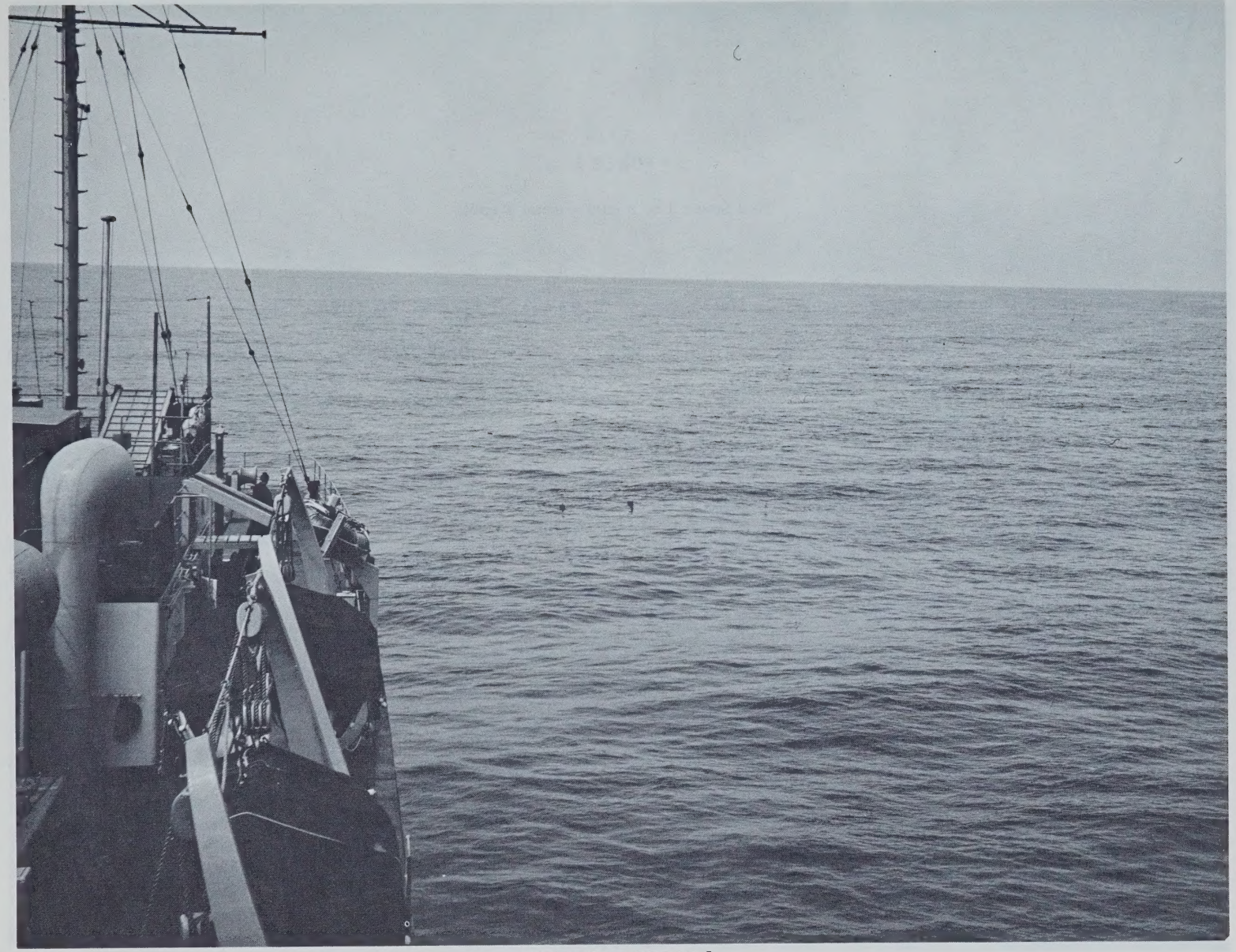
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	–	–	–
Swell	290	10	3

SYNOPTIC SITUATION

The station was near the centre of a narrow ridge of high pressure which extended northward into the Gulf of Alaska from a high centred near 30°N, 147°W. A low pressure area, elongated in a north-south direction, lay just off the coast of Canada and the U.S.A. Another low was centred in the eastern Bering Sea.

REMARKS

Winds averaged less than 3 knots (Force 1) over the previous 14 hours, and less than 6 knots (Force 2) over the previous 24 hours. Air temperature 44°F, sea temperature 44°F.



BEAUFORT FORCE 1

FORCE 1

Wind Speed 1 to 3 knots, mean 2 knots

Sea Criterion: Ripples with the appearance of scales are formed, but without foam crests.

Date/Time of Photograph: July 30, 1960, 2245 G.M.T.

Height of Camera above sea: 35 feet

WIND	DIRECTION (°T)	SPEED (KTS)
At 2245 G.M.T.	170	03
2100	–	Calm
1800	260	04
1500	320	09
1200	310	12
0900	310	09
0600	270	10
0300	250	05
0000	260	06

WAVES AT TIME OF PICTURE

	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	–	–	–
Swell	300	7	4

SYNOPTIC SITUATION

Low pressure area centred 250 nautical miles southwest of station moving eastward. High pressure ridge 180 nautical miles northeast of station lying in a northwest-southeast line. Station was in a light southeasterly circulation to the east of the advancing low.

REMARKS

Wind speeds averaged approximately 2 knots (Force 1) during the previous 5 hours, backing from west to south in this interval. The mean wind speed over the previous 24 hours was slightly over 6 knots (Force 3). Air temperature 55°F, sea temperature 55°F.

BEAUFORT FORCE 1

FORCE 2

Wind Speed 4 to 6 knots, mean 5 knots

Sea Criterion: Small wavelets, still short but more pronounced – crests have a glassy appearance and do not break.

Date/Time of Photograph: April 22, 1961, 1615 G.M.T.

Height of camera above sea: 45 feet

WIND	DIRECTION (°T)	SPEED (KTS)
At 1615 G.M.T.	180	05
1500	210	05
1200	230	04
0900	320	06
0600	320	04
0300	300	09
0000	280	10
2100	300	07
1800	330	06

WAVES AT TIME OF PICTURE

	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	180	–	–
Swell	340	8	4

SYNOPTIC SITUATION

Ridge of high pressure, lying in a north-south direction, 100 nautical miles east of station. Low pressure area centred 550 nautical miles west-southwest of station. Ridge line passed station four to seven hours previously, and ship now in southeasterly circulation ahead of low.

REMARKS

Wind speed averaged 5.5 knots (Force 2) during previous 13 hours but direction backed from northwest to south. Mean speed over previous 24 hours was slightly more than 6 knots (Force 3). Air temperature 42.9°F, sea temperature 41.2°F.

BEAUFORT FORCE 2

FORCE 2

Wind Speed 4 to 6 knots, mean 5 knots

Sea Criterion: Small wavelets, still short but more pronounced – crests have a glassy appearance and do not break.

Date/Time of Photograph: May 26, 1961, 1700 G.M.T.

Height of camera above sea: 45 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 1700 G.M.T.	120	05
1500	100	03
1200	–	Calm
0900	340	06
0600	010	07
0300	340	03
0000	320	04
2100	310	04
1800	310	03

WAVES AT TIME OF PICTURE

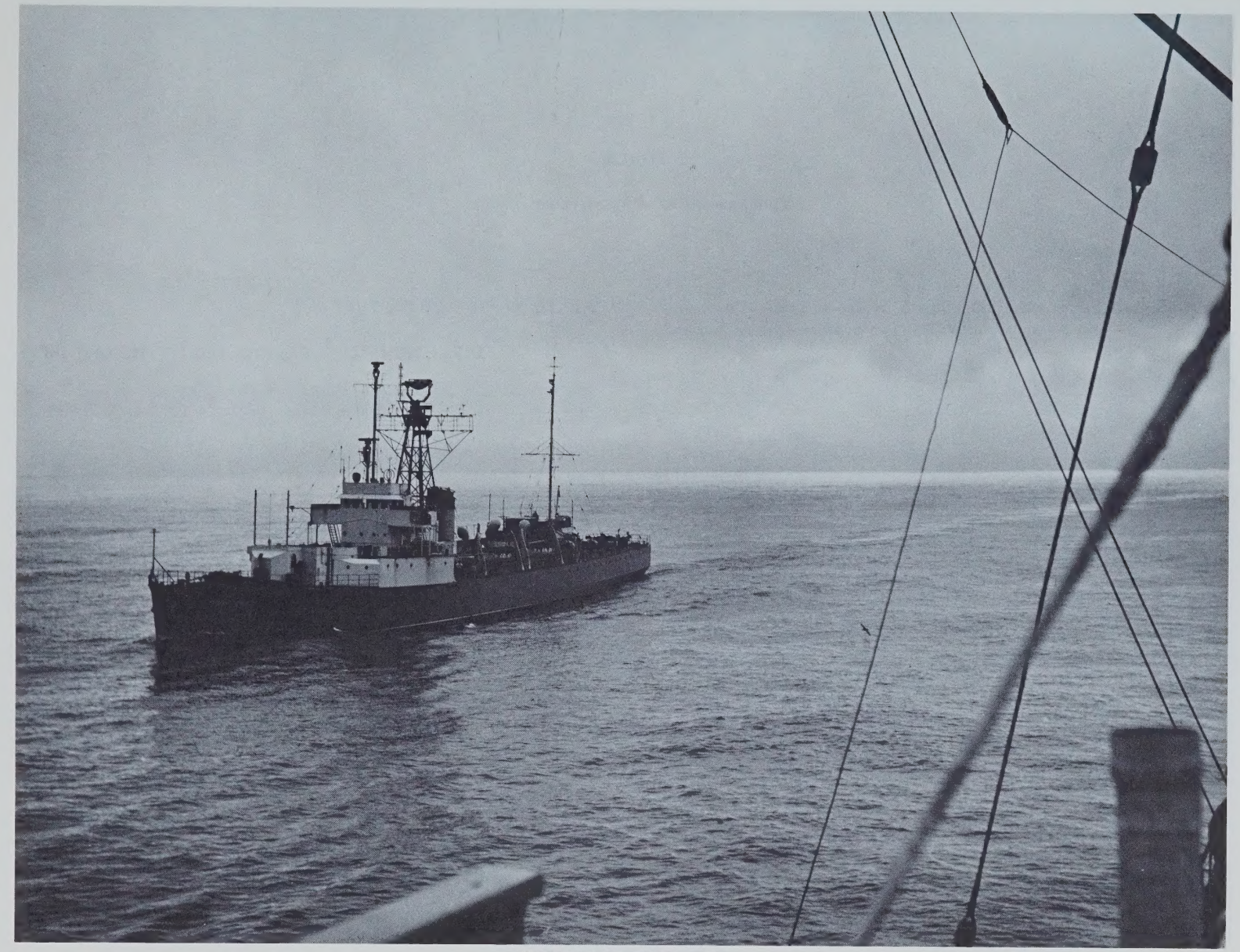
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	120	–	–
Swell	050	6	1

SYNOPTIC SITUATION

A weak trough of low pressure, lying in a general northwest-southeast direction, was immediately west of the ship and passed by during the next hour. The centreline of the following ridge of high pressure was approximately 400 nautical miles west of the ship.

REMARKS

This picture, taken from the C.C.G.S. ST. CATHARINES, shows her sister ship the C.C.G.S. STONETOWN, and was taken at 49.8°N, 142.5°W, or approximately 100 nautical miles east of the Station "P" position. The wind speed averaged close to 4 knots (Force 2) during the previous 24 hours. Air temperature 46.5°F, sea temperature 45.0°F.



BEAUFORT FORCE 2

FORCE 3

Wind Speed 7 to 10 knots, mean 9 knots

Sea Criterion: Large wavelets. Crests begin to break. Foam of a glassy appearance. Perhaps scattered white horses.

Date/Time of Photograph: November 9, 1960, 0015 G.M.T.

Height of camera above sea: 45 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 0015 G.M.T.	080	08
2100	070	07
1800	030	07
1500	010	04
1200	360	04
0900	340	07
0600	300	07
0300	300	07
0000	310	14

WAVES AT TIME OF PICTURE

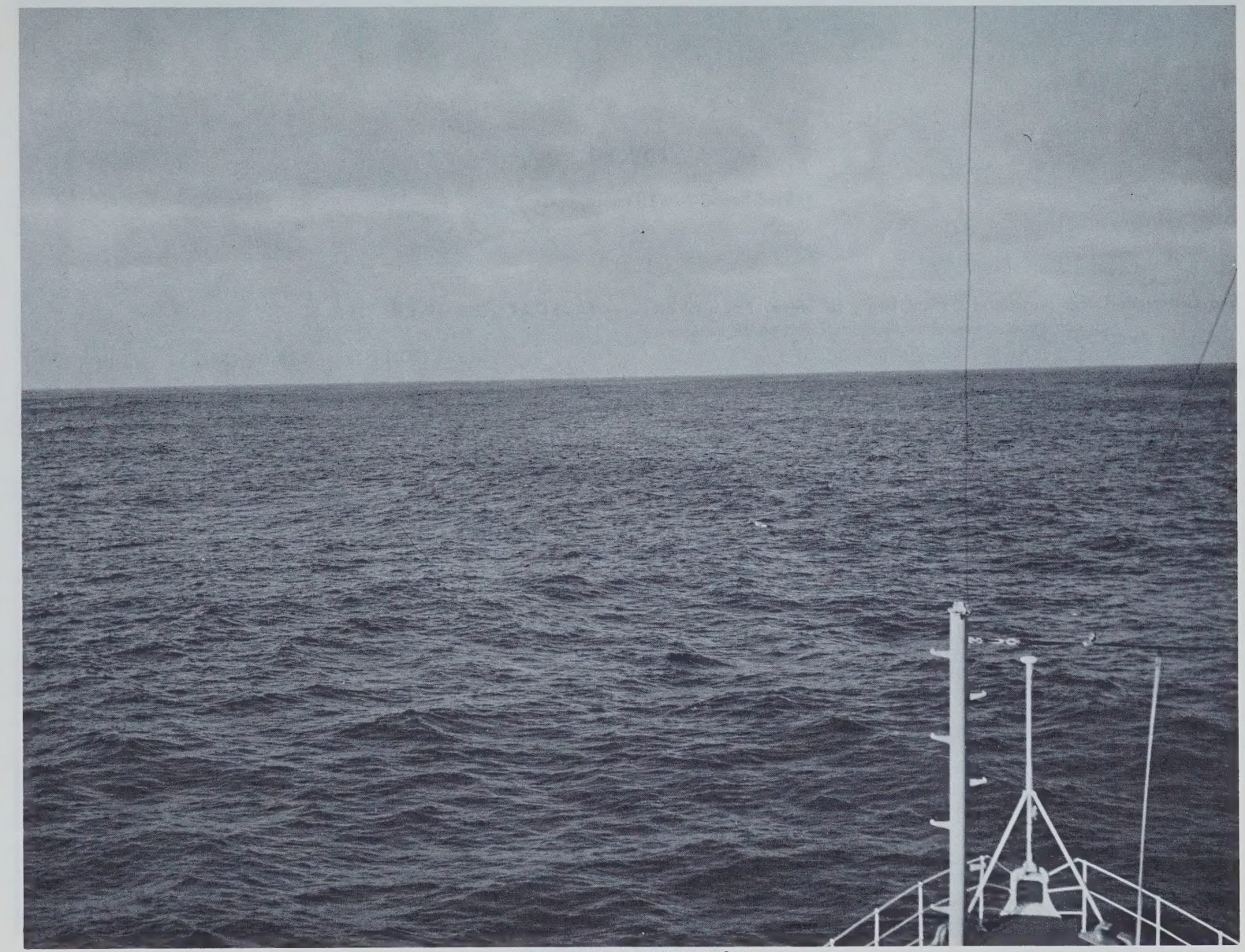
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	080	3	1
Swell	260	8	7

SYNOPTIC SITUATION

Weak low pressure area centred at 44°N, 142°W, 360 nautical miles south-southeast of station. Intense low pressure area centred in southern Bering Sea with strong southerly circulation over the Pacific Ocean to 150°W.

REMARKS

Wind speed averaged greater than 7 knots (Force 3) during the previous 6 hours. The mean speed over the previous 24 hours was 7.2 knots (Force 3), but the direction veered from northwest to east-northeast during the period. Air temperature 47.2°F, sea temperature 48.3°F.



BEAUFORT FORCE 3

FORCE 3

Wind Speed 7 to 10 knots, mean 9 knots

Sea Criterion: Large wavelets. Crests begin to break. Foam of a glassy appearance. Perhaps scattered white horses.

Date/Time of Photograph: February 19, 1961, 2000 G.M.T.

Height of camera above sea: 45 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2000 G.M.T.	190	03
1800	160	09
1500	180	10
1200	190	11
0900	260	08
0600	300	10
0300	320	10
0000	010	16
2100	090	10

WAVES AT TIME OF PICTURE

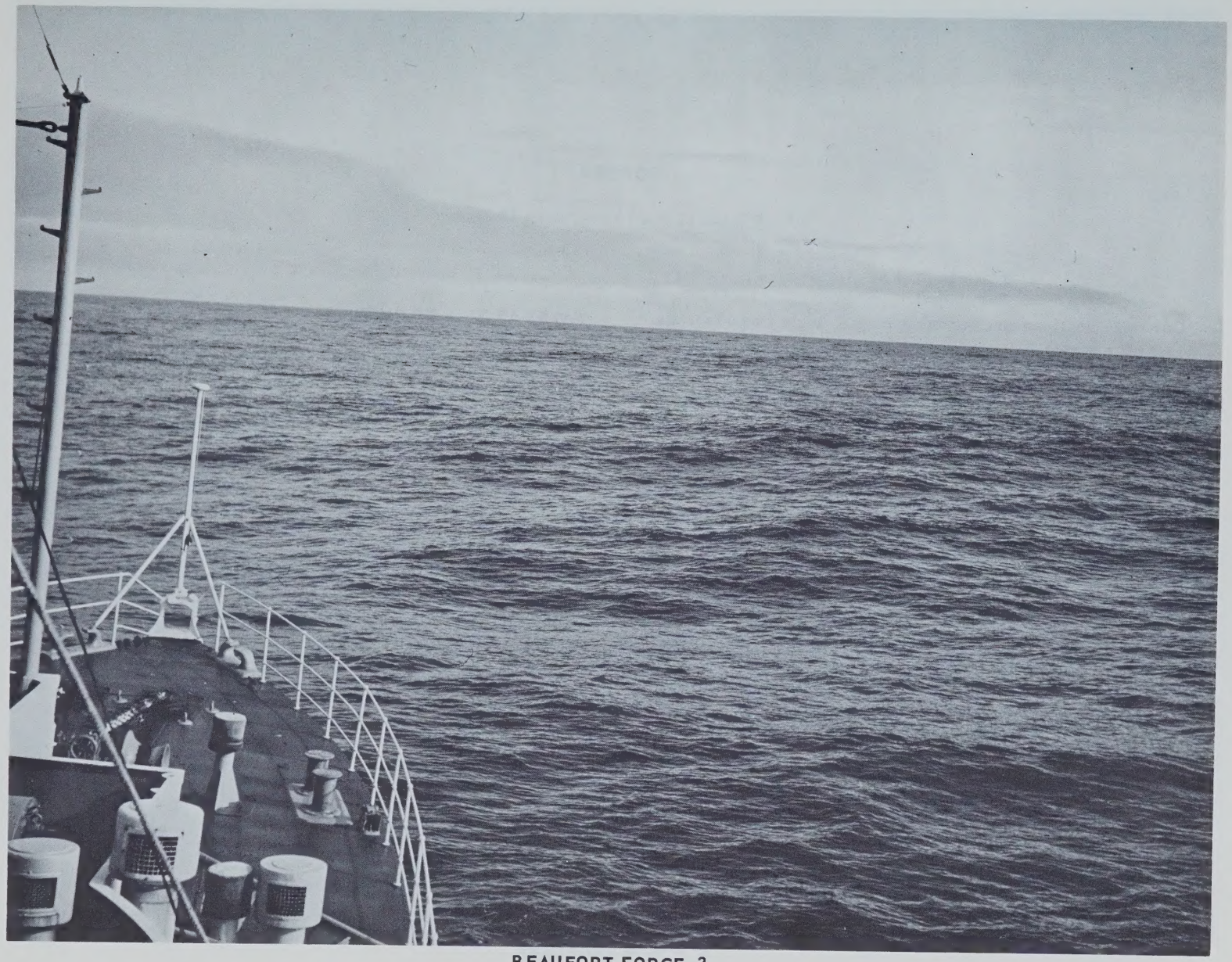
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	–	–	–
Swell	180	7	8

SYNOPTIC SITUATION

Small low pressure area centred approximately 170 nautical miles west of station. Ship was approximately 40 nautical miles north of a warm front which extended eastward from the low centre.

REMARKS

Although the wind speed at the time of this picture was only 3 knots (Force 1), it had decreased from 9 knots two hours previously, and had averaged almost 10 knots over the previous 24 hours. The direction had been constant from the south for 8 hours. Air temperature 44.2°F, sea temperature 40.8°F.



BEAUFORT FORCE 3

FORCE 4

Wind Speed 11 to 16 knots, mean 13 knots

Sea Criterion: Small waves, becoming longer, fairly frequent white horses.

Date/Time of Photograph: September 16, 1960, 2315 G.M.T.

Height of camera above sea: 45 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2315 G.M.T.	250	11
2100	250	11
1800	270	11
1500	300	15
1200	270	14
0900	270	10
0600	280	24
0300	280	16
0000	170	18

WAVES AT TIME OF PICTURE

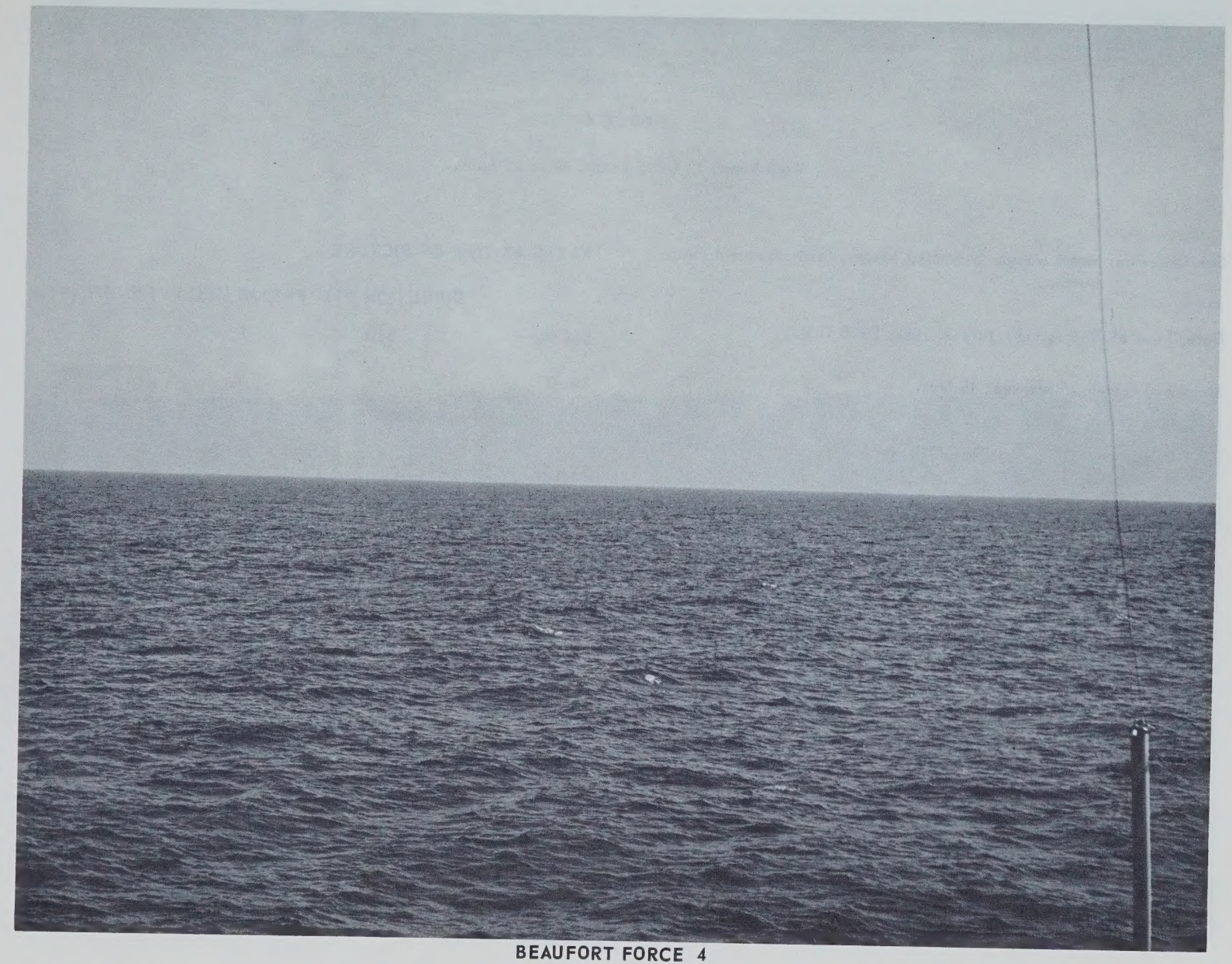
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	250	5	3
Swell	–	–	–

SYNOPTIC SITUATION

The ship was just east of a weak ridge of high pressure which lay in northwest-southeast direction to the west. A low pressure area was centred approximately 500 nautical miles west-southwest of the ship.

REMARKS

This picture was made at 49.7°N, 140.8°W, or approximately 160 nautical miles east of the Station "P" position. The wind was fairly constant in both speed and direction over the previous 24 hours. Air temperature 57.0°F, sea temperature 55.9°F.



BEAUFORT FORCE 4

FORCE 4

Wind Speed 11 to 16 knots, mean 13 knots.

Sea Criterion: Small waves, becoming longer, fairly frequent white horses.

Date/Time of Photograph: July 3, 1960, 2240 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2240 G.M.T.	320	16
2100	320	16
1800	340	11
1500	270	05
1200	270	08
0900	140	08
0600	230	09
0300	260	09
0000	250	13

Note: Between 0000 and 2240 G.M.T., the ship had travelled eastward from 49.3° N, 133.7° W to 48.8° N, 128.2° W, a distance of approximately 220 nautical miles.

WAVES AT TIME OF PICTURE

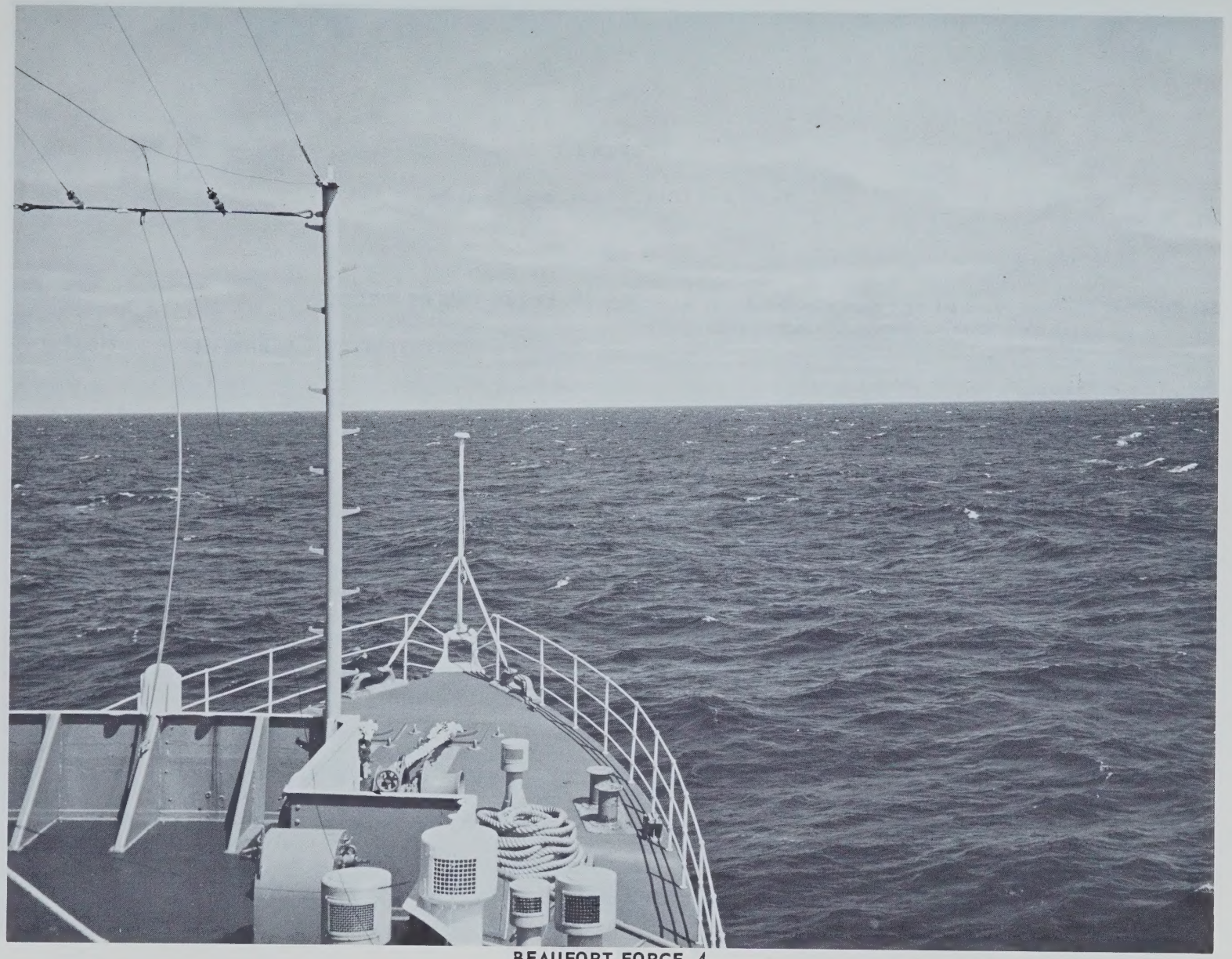
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	310	5	3
Swell	–	–	–

SYNOPTIC SITUATION

High pressure area centred at 40° N, 137° W with ridge line extending northeastward to 100 nautical miles west of ship, thence northward to northern section of British Columbia Coast. Low pressure area centred at 55° N, 150° W in Gulf of Alaska.

REMARKS

This picture was made at 48° 48'N, 128° 12'W, or approximately 200 nautical miles west of Vancouver while the ship was returning from Station "P". The ship was moving into the area of northwesterly circulation east of the ridge of high pressure, and had passed the ridge line approximately eleven hours before the time of this picture. It is likely that Force 4 winds had been acting on the area longer than would appear from the wind data, as the ship was moving eastward into the area. Air temperature 55.6° F, sea temperature 52.7° F.



BEAUFORT FORCE 4

FORCE 5

Wind Speed 17 to 21 knots, mean 19 knots.

Sea Criterion: Moderate waves taking a more pronounced long form; many white horses are formed. (Chance of some spray).

Date/Time of Photograph: April 7, 1961, 2315 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2315 G.M.T.	280	23
2100	270	19
1800	240	20
1500	220	21
1200	220	24
0900	200	26
0600	190	25
0300	180	27
0000	180	30

WAVES AT TIME OF PICTURE

	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	280	6	7
Swell	240	8	6

SYNOPTIC SITUATION

High pressure area centred 550 nautical miles southeast of station which was in a northwesterly circulation 200 nautical miles northeast of the ridge line extending northwestward from the High. Low pressure area centred near 56° N, 136° W, in Gulf of Alaska.

REMARKS

The wind speed at the time of the picture was 23 knots (Force 6), but had averaged less than 21 knots (Force 5) over the previous 8 hours. In this period the wind veered from southwest to west. Air temperature 41.0° F, sea temperature 41.2° F.

BEAUFORT FORCE 5

FORCE 5

Wind Speed 17 to 21 knots, mean 19 knots.

Sea Criterion: Moderate waves, taking a more pronounced long form; many white horses are formed. (Chance of some spray).

Date/Time of photograph: April 10, 1961, 2300 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2300 G.M.T	190	20
2100	200	23
1800	170	20
1500	190	22
1200	170	13
0900	170	07
0600	170	07
0300	180	04
0000	190	06

WAVES AT TIME OF PICTURE

	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	180	4	4
Swell	230	7	7

SYNOPTIC SITUATION

Station was in southerly circulation between a large high pressure area centered at 41° N, 138° W, 600 nautical miles to the southeast, and a trough of low pressure extending from 44° N, 160° W northeastward to the Gulf of Alaska.

REMARKS

The wind had been blowing from the south at Force 5 for the previous 8 hours, the speed having increased from Force 2 in the 12 hour period from 0300 G.M.T. Air temperature 43.8° F, sea temperature 42.3° F.

BEAUFORT FORCE 5

FORCE 6

Wind Speed 22 to 27 knots, mean 24 knots.

Sea Criterion: Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray).

Date/Time of photograph: February 10, 1961, 2115 G.M.T.

Height of camera above sea: 20 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2115 G.M.T.	280	25
1800	300	26
1500	300	14
1200	280	23
0900	280	26
0600	310	23
0300	300	26
0000	280	27

WAVES AT TIME OF PICTURE

	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	280	6	11
Swell	–	–	–

SYNOPTIC SITUATION

Station in a northwesterly flow south of a low pressure area centred at 56° N, 144° W, 380 nautical miles north of ship. Trough of low pressure extending southeastward from low to second low lying off western coast of U.S.A. Ridge of high pressure 300 nautical miles west of ship.

REMARKS

Except for a period between 3 and 9 hours ago, the wind was fairly constant, in both speed and duration, over the previous 24 hours. The fetch of the wind at the time of the picture was at least 300 nautical miles. Air temperature 37.4° F, sea temperature 41.0° F.

BEAUFORT FORCE 6

FORCE 6

Wind Speed 22 to 27 knots, mean 24 knots

Sea Criterion: Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray).

Date/Time of Photograph: April 7, 1961, 0300 G.M.T.

Height of camera above sea: 18 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 0300 G.M.T.	180	27
0000	180	30
2100	170	23
1800	170	28
1500	170	23
1200	170	25
0900	170	18
0600	160	12
0300	140	12

WAVES AT TIME OF PICTURE

	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	180	7	10
Swell	200	9	10

SYNOPTIC SITUATION

High pressure area centred at 45° N, 135° W, 500 nautical miles southeast of ship, with ridge extending northward into the Gulf of Alaska. Trough of low pressure extending northward to Alaska from low centred at 41° N, 158° W.

REMARKS

The wind speed averaged 26 knots (Force 6) over the previous 15 hours, although Force 7 winds were reported at two synoptic hours in this interval. The fetch of the wind was approximately 350 nautical miles. Air temperature 43.4° F, sea temperature 41.5° F.

BEAUFORT FORCE 6

FORCE 7

Wind Speed 28 to 33 knots, mean 30 knots.

Sea Criterion: Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.

Date/Time of Photograph: April 28, 1961, 2130 G.M.T.

Height of camera above sea: 45 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2130 G.M.T.	090	29
2100	100	30
1800	110	33
1500	120	31
1200	110	45
0900	090	36
0600	040	31
0300	040	35
0000	030	30

WAVES AT TIME OF PICTURE

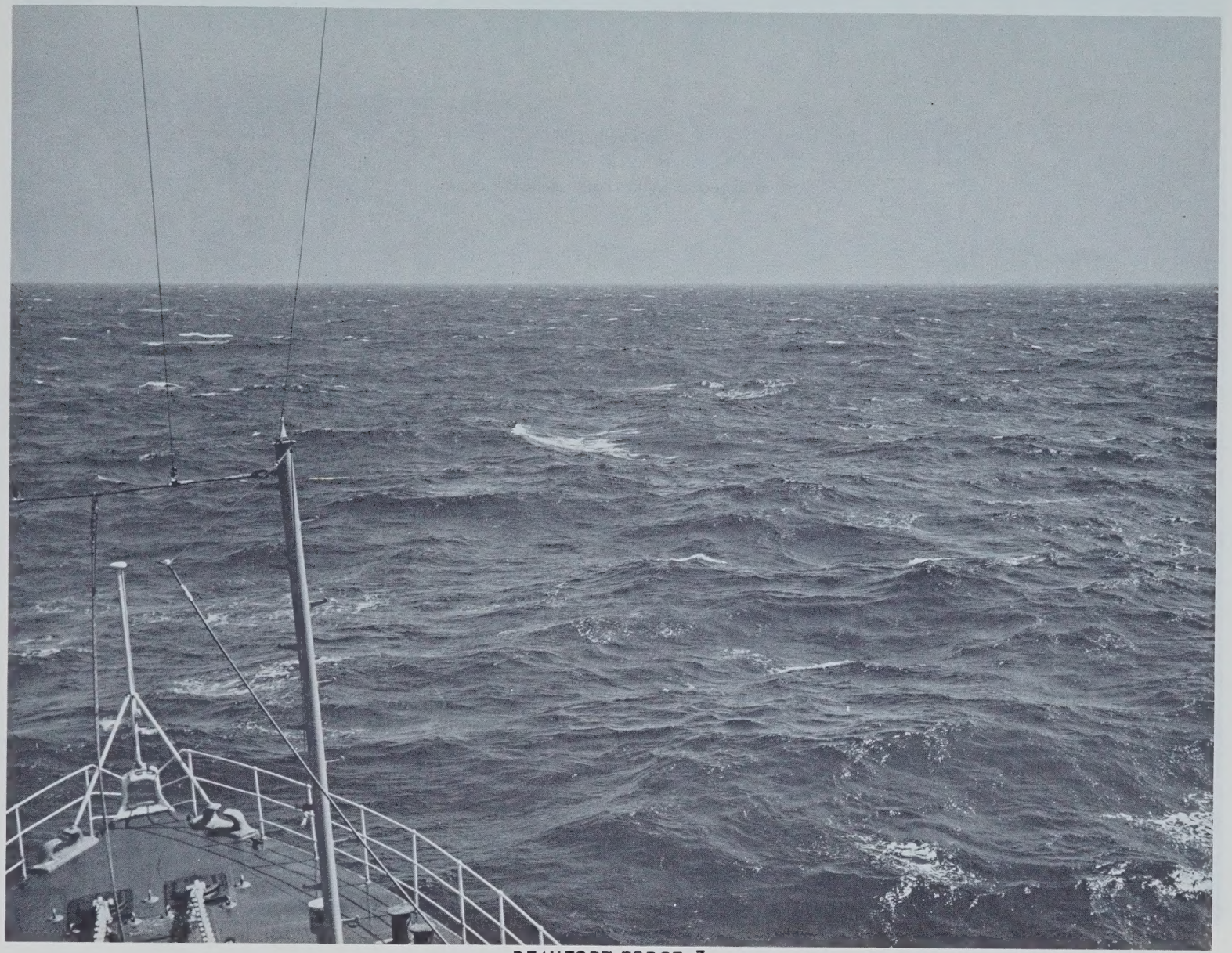
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	100	6	21
Swell	–	–	–

SYNOPTIC SITUATION

Station in an easterly circulation north of a low pressure area centred 250 nautical miles south of the ship.

REMARKS

The wind speed had been Force 7 for the past 6½ hours, and had averaged Force 7 over the previous 24 hours. The picture illustrates well how Force 7 winds begin to blow the foam in streaks over the sea surface. Fetch of wind approximately 200 nautical miles. Air temperature 44.6° F, sea temperature 41.2° F.



BEAUFORT FORCE 7

FORCE 7

Wind Speed 28 to 33 knots, mean 30 knots.

Sea Criterion: Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.

Date/Time of Photograph: February 28, 1961, 1900 G.M.T.

Height of camera above sea: 45 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 1900 G.M.T.	300	30
1800	300	30
1500	260	35
1200	260	35
0900	270	30
0600	250	38
0300	220	39
0000	210	39
2100	180	30

WAVES AT TIME OF PICTURE

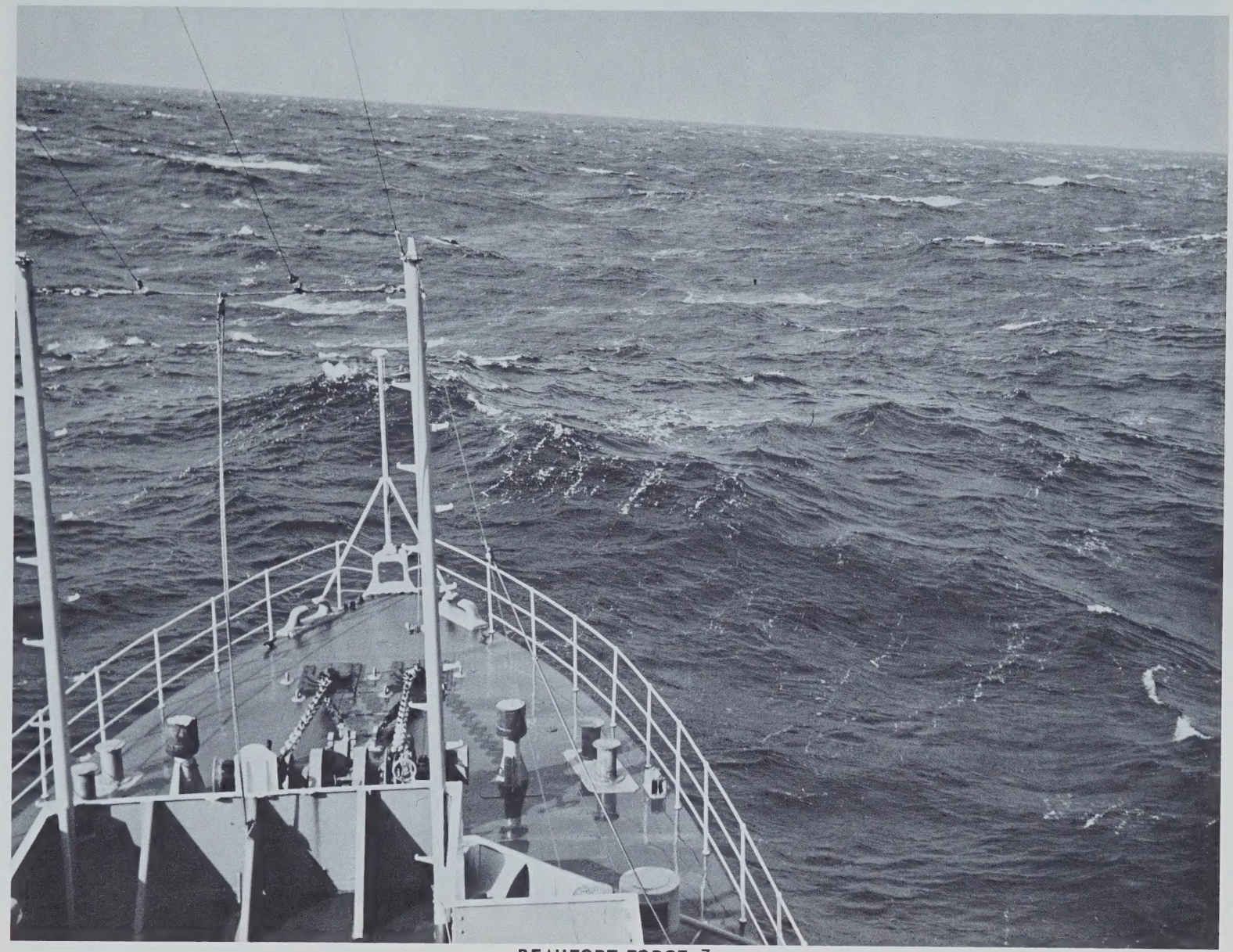
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	300	6	13
Swell	250	9	10

SYNOPTIC SITUATION

A deep low pressure area centred at 60° N, 144° W, dominated the northeastern Pacific east of 160° W and north of 45° N. Station in northwesterly circulation approximately 575 nautical miles south of low centre.

REMARKS

Although the wind speed was Force 7 at the time of the picture, it had decreased from low Force 8 between one and four hours previously. The wind veered from south to northwest during the previous 24 hours as the low centre passed west of the ship while moving northward into the Gulf of Alaska. Fetch of the wind at the time of the picture was approximately 350 nautical miles. Air temperature 38.4° F, sea temperature 40.7° F.



BEAUFORT FORCE 7

FORCE 8

Wind Speed 34 to 40 knots, mean 37 knots.

Sea Criterion: Moderately high waves of greater length; edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind.

Date/Time of photograph: January 15, 1961, 1955 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 1955 G.M.T.	250	45
1800	240	38
1500	240	38
1200	250	37
0900	250	35
0600	250	35
0300	250	43
0000	250	40
2100	240	30

WAVES AT TIME OF PICTURE

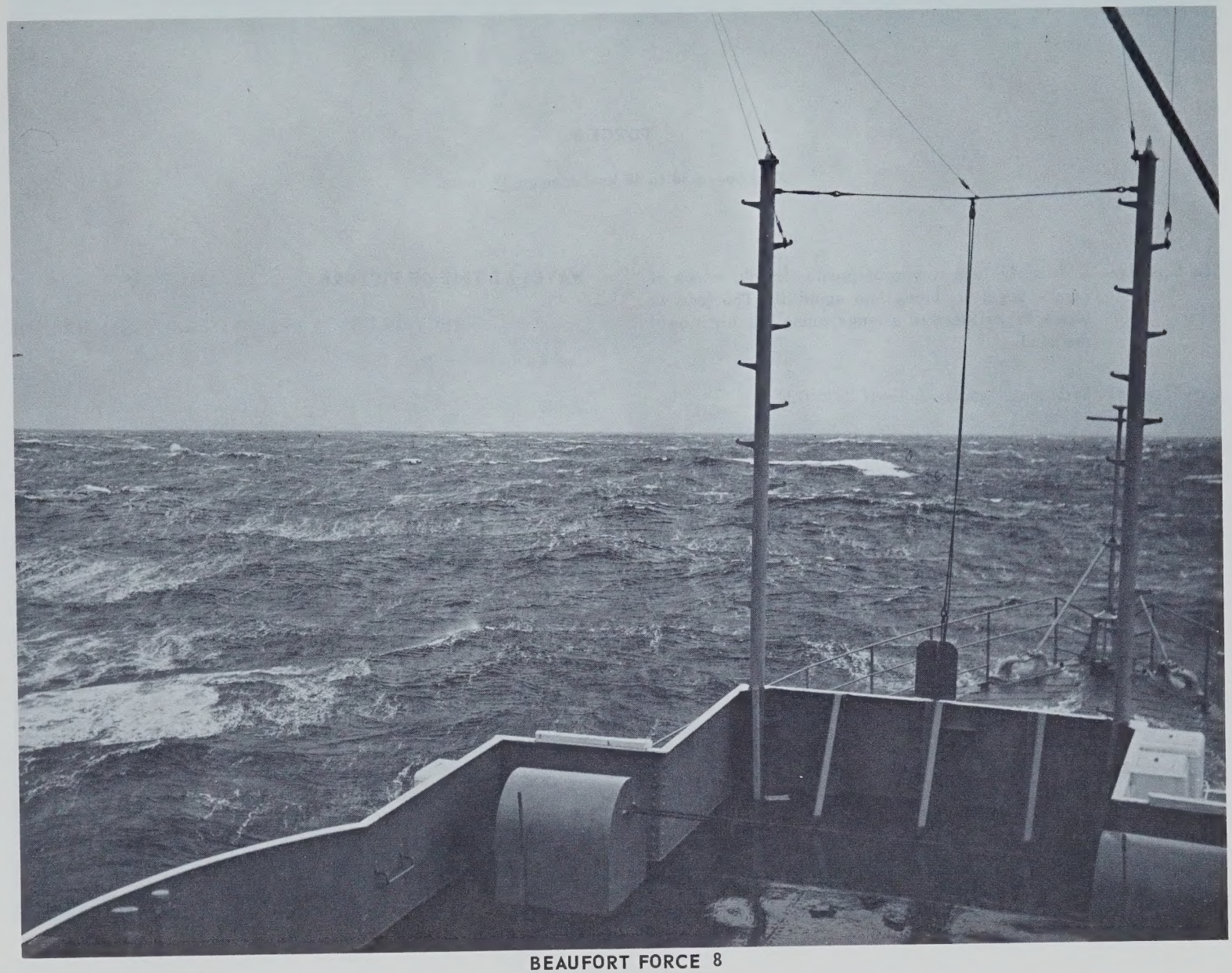
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	260	7	18
Swell	–	–	–

SYNOPTIC SITUATION

Low pressure area centred at 58° N, 142° W in the Gulf of Alaska. Station in southwesterly circulation 500 nautical miles south-southwest of low centre.

REMARKS

Although the wind speed at the time of the picture was 45 knots (Force 9), it had been Force 8 for 12 hours previously, and increased in speed less than two hours prior to the picture. The wind direction was remarkably constant at 240° to 250° over the previous 24 hours. Air temperature 39.0° F, sea temperature 41.2° F.



BEAUFORT FORCE 8

FORCE 8

Wind Speed 34 to 40 knots, mean 37 knots.

Sea Criterion: Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.

Date/Time of Photograph: January 2, 1961, 2330 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2330 G.M.T.	210	35
2100	200	38
1800	210	39
1500	210	35
1200	240	52
0900	220	60
0600	180	25
0300	210	25
0000	200	35

WAVES AT TIME OF PICTURE

	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	210	6	16
Swell	–	–	–

SYNOPTIC SITUATION

Deep low pressure area centred at 55° N, 154° W. The station was in a southwesterly circulation 450 nautical miles southeast of the low centre.

REMARKS

The wind speed had been Force 8 during the previous 8½ hours, and the direction constant at 200° to 210°. At 0900 and 1200 G.M.T. (14½ and 11½ hours previously) the wind was Force 10 and 11 respectively, and attained briefly a speed of 82 knots between the above hours. Air temperature 44.1° F, sea temperature 42.7° F.

BEAUFORT FORCE 8

FORCE 9

Wind Speed 41 to 47 knots, mean 44 knots.

Sea Criterion: High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.

Date/Time of Photograph: November 16, 1960, 2245 G.M.T.

Height of Camera above sea: 45 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2245 G.M.T.	225	43
2100	220	43
1800	220	41
1500	210	35
1200	190	42
0900	170	39
0600	140	19
0300	180	12
0000	230	12

WAVES AT TIME OF PICTURE

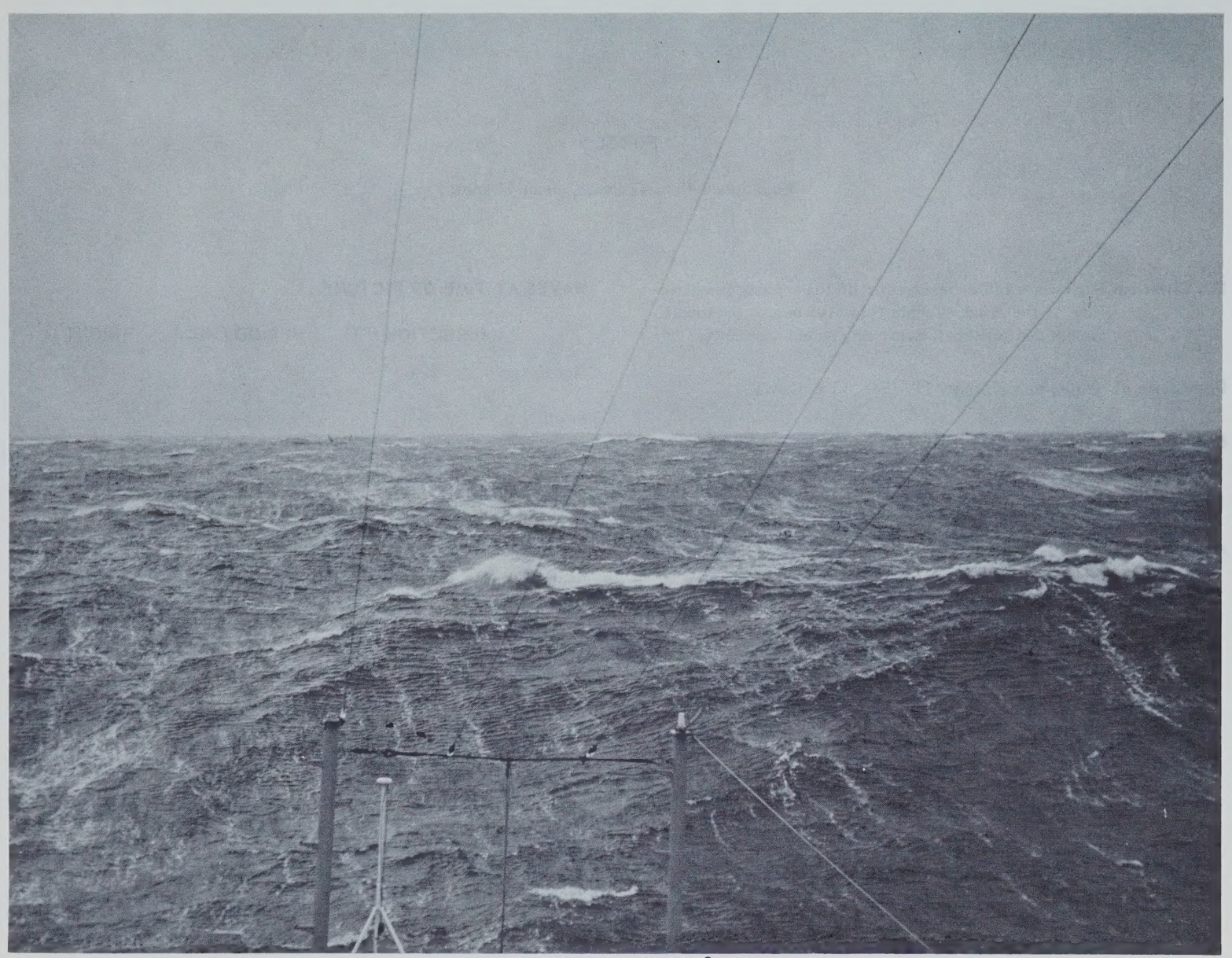
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	220	9	25
Swell	–	–	–

SYNOPTIC SITUATION

Deep low pressure area centred at 55° N, 149° W, or 330 nautical miles northwest of station. Low centre moving northeastward at approximately 40 knots.

REMARKS

The wind had been Force 9 for the past 5 hours, and had averaged Force 9 over the previous 11 hours. Although the general appearance of the sea surface conforms well to the Sea Criterion for Force 9, the wave heights have obtained only above 60% of their maximum height due to insufficient duration of the blow. Air temperature 46.0° F, sea temperature 47.1° F.



BEAUFORT FORCE 9

FORCE 9

Wind Speed 41 to 47 knots, mean 44 knots.

Sea Criterion: High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.

Date/Time of Photograph: January 17, 1961, 2130 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2130 G.M.T.	120	50
2100	120	48
1800	120	46
1500	110	44
1200	110	30
0900	120	17
0600	140	08
0300	–	Calm
0000	250	10

WAVES AT TIME OF PICTURE

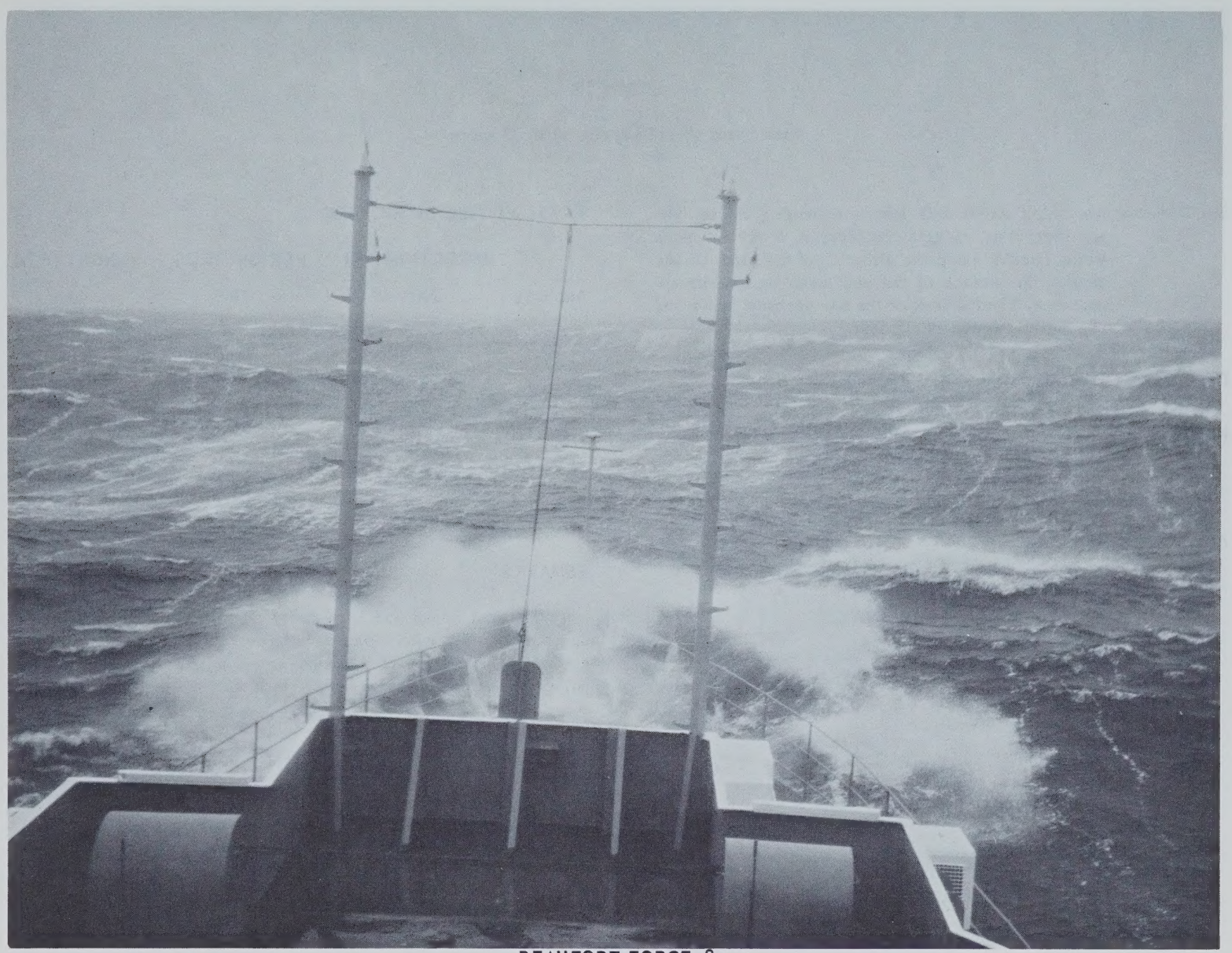
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	120	7	20
Swell	–	–	–

SYNOPTIC SITUATION

Station in strong southeasterly circulation, approximately 600 nautical miles east-northeast of a deep low centred about 48° N, 160° W.

REMARKS

Although the wind speed was 50 knots (Force 10) at the time of the picture, the average speed over the previous 9½ hours was Force 9. The wind had increased from calm conditions 18 hours ago. The appearance of the sea surface conforms well to the Force 9 specification, but the reported wave heights are only 50% of the maximum theoretical height for Force 9. It would be necessary for the wind to blow another 15 to 20 hours at Force 9 before the waves approached their maximum height. Air temperature 42.1° F, sea temperature 41.6° F.



BEAUFORT FORCE 9

FORCE 10

Wind Speed 48 to 55 knots, mean 52 knots.

Sea Criterion: Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected.

Date/Time of Photograph: November 17, 1960, 2215 G.M.T.

Height of camera above sea: 35 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2215 G.M.T.	290	52
2100	290	50
1800	290	50
1500	280	48
1200	260	56
0900	240	49
0600	230	48
0300	220	46
0000	230	45

WAVES AT TIME OF PICTURE

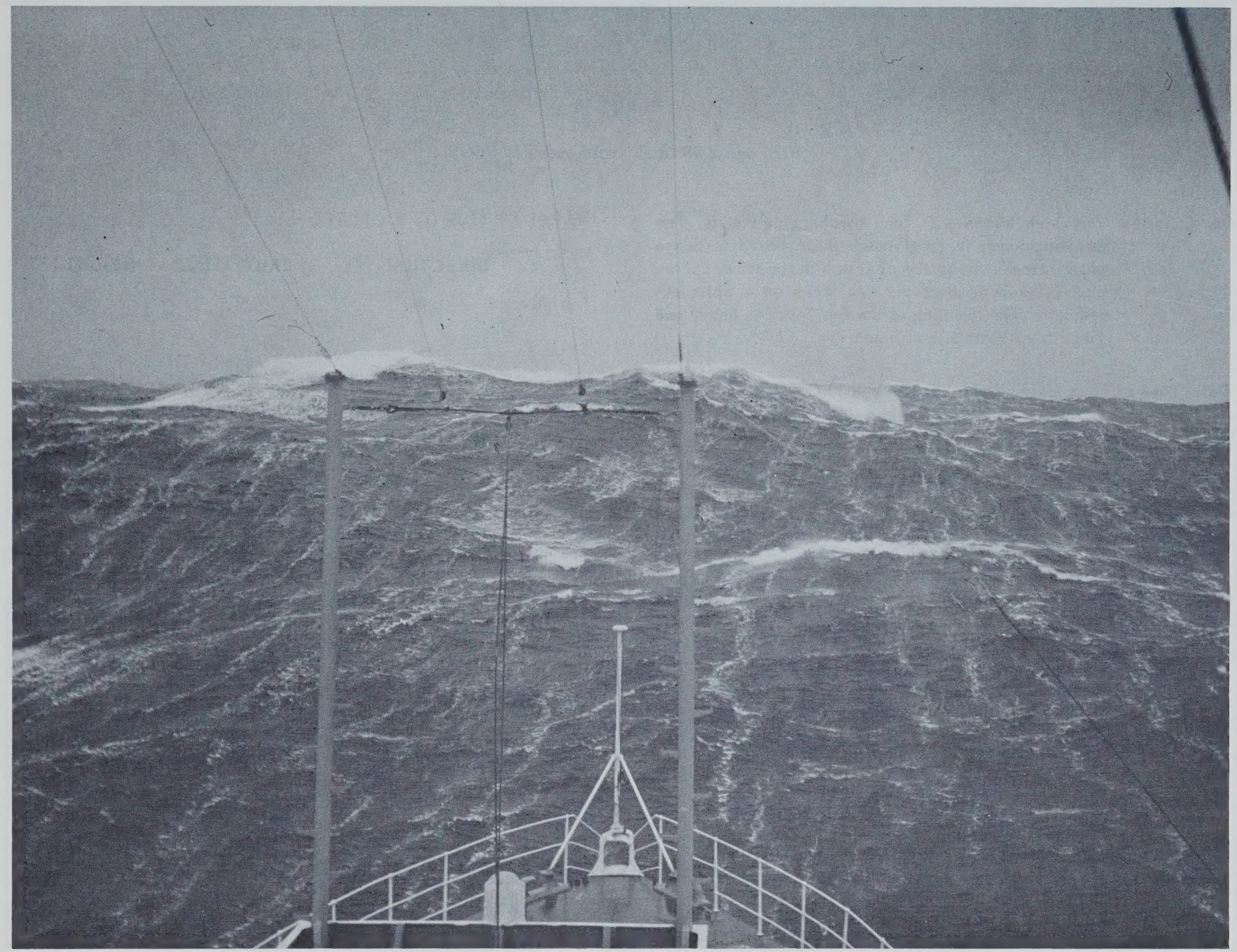
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	290	10	40
Swell	–	–	–

SYNOPTIC SITUATION

Station in northwesterly circulation 420 nautical miles southwest of a deep low pressure area centred at 57° N, 142° W.

REMARKS

The wind speed had been fairly constant at Force 10 for the past 16 hours. The wind direction had veered from southwest to westnorthwest. The fetch of the wind was approximately 300 nautical miles. Air temperature 43.2° F, sea temperature 46.2° F.



BEAUFORT FORCE 10

FORCE 10

Wind Speed 48 to 55 knots, mean 52 knots.

Sea Criterion: Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected.

Date/Time of Photograph: March 14, 1961, 2330 G.M.T.

Height of camera above sea: 15 feet.

WIND	DIRECTION (°T)	SPEED (KTS)
At 2330 G.M.T.	340	55
2100	350	52
1800	360	55
1500	010	52
1200	010	44
0900	030	43
0600	030	29
0300	040	17
0000	050	12

WAVES AT TIME OF PICTURE

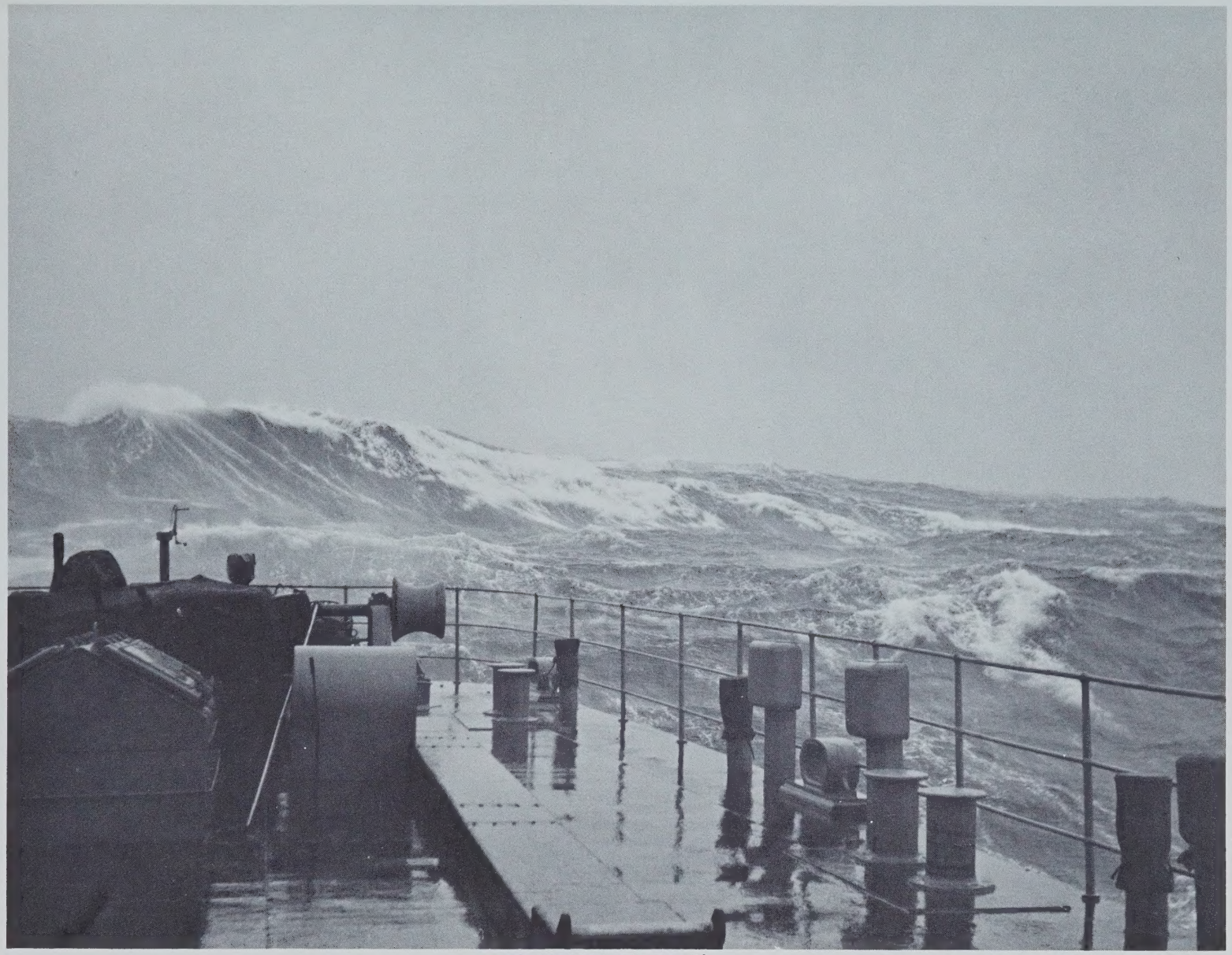
	DIRECTION (°T)	PERIOD (SEC.)	HEIGHT (FT.)
Sea Waves	340	9	22
Swell	–	–	–

SYNOPTIC SITUATION

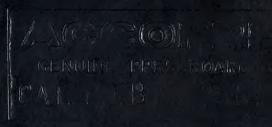
Deep low pressure area centred at 49° N, 138° W, moving northeastward. Station in strong northerly circulation 250 nautical miles west-northwest of low centre.

REMARKS

The wind had been blowing at Force 10 for the past 8½ hours, the direction backing from 010° to 340°. Because of the relatively short duration of the Force 10 winds, the wave heights have only attained roughly 50% of their maximum height for this Force. The fetch of the wind at the time of the picture was estimated to lie between 150 and 200 nautical miles. Air temperature 37.6° F, sea temperature 40.0° F.



BEAUFORT FORCE 10



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